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SUPERIMPOSED STEERING SYSTEM FOR A VEHICLE

The invention relates to a superimposed steering system for a vehicle, in particular a power steering system or a power assistance steering system for a motor vehicle, according to the precharacterizing clause of claim 1.

Superimposed steering systems are known and are distinguished by the fact that, if required, a further rotational angle can be superimposed by an actuator on the steering angle which is selected on a steering handle by a driver of a vehicle. The additional rotational angle is controlled by an electronic control and/or regulating device and serves to increase the driving stability of the vehicle or other purposes.

In order to produce an additional angle or a further rotational angle, it is known from DE 101 29 450 A1 and DE 101 60 313 A1 to use a planetary gear mechanism as variable ratio gear unit, a steering shaft which is connected to a first gear unit input shaft being disconnected axially and being connected rotatably by a multistep planet which moves around sun gears of the steering shaft parts. The multistep planets are mounted in a planetary gear carrier. The planetary gear carrier can in turn be moved about the steering shaft and its sun gears with a helical gear mechanism or a worm gear mechanism, the rotational movement of the planetary gear carrier being carried out with the aid of a helical gear or worm on a second gear unit input shaft of the variable ratio gear unit.

Variable ratio gear units of this type have a large number of toothing engagements. This results in gear unit play which can produce undesirable steering play. In addition, the

abovedescribed variable ratio gear units with servomotor are relatively complicated and expensive in technical terms.

DE 102 20 123 A1 discloses a superimposed steering system, an electric servomotor drive being integrated into a steering column shaft which connects a steering wheel to a steering gear. The electric servomotor drive has a housing which is connected to a first section of the steering column shaft and a drive shaft which is connected to a second section of the steering column shaft. The first section of the steering column shaft is connected to a steering wheel and the second section is connected to the steering gear, or vice versa. The drive shaft can be rotated by the electric servomotor drive relative to the housing of the electric servomotor drive, in order to produce an additional rotational angle. Although an additional angle is superimposed with this superimposed steering system on a rotational movement between the steering wheel and the steering gear, the opposing torque of the electric servomotor drive is supported on the steering column shaft, which can lead to an uncomfortable steering or driving sensation for a driver.

Superimposed steering systems are known which have a harmonic drive or pulsator drive as variable ratio gear unit. However, the servomotor of harmonic drives of this type supports its torque on the steering column. In addition, these harmonic drives require a stable housing in order to transmit the torque and the rotational angle at the steering handle to the gear unit output shaft of the variable ratio gear unit.

The invention is based on the object of providing a playfree superimposed steering system for a vehicle, which superimposed steering system offers comfortable handling, has a simple construction and the installation space for which is minimized.

The object is achieved with a superimposed steering system having the features of claim 1.

For this purpose, the variable ratio gear unit can be configured without a housing, in that the torque and the rotational angle on the steering handle and the first gear unit input shaft are transmitted directly to the radially flexible flexspline of the harmonic drive via a releasable connection. Here, the first gear unit input shaft penetrates an eccentric, preferably elliptical drive core of the harmonic drive, which drive core protrudes in the radial direction in the manner of a cam into the radially flexible flexspline and is connected fixedly in terms of rotation to the second gear unit input shaft and the servomotor.

Preferred refinements result from the subclaims.

The harmonic drive has a first gear unit input shaft which is connected fixedly in terms of rotation to the steering shaft and the steering handle of the vehicle. The second gear unit input shaft is configured as a hollow shaft which is driven by the servomotor. The second gear unit input shaft is connected fixedly in terms of rotation to the eccentric, in particular elliptical drive core of the harmonic drive. The eccentric drive core engages axially into the radially flexible flexspline of the harmonic drive, one or more circumferential sections of an outer circumferential surface of the radially flexible flexspline being engaged in a continuously changing manner with a substantially cylindrical supporting surface of a circular spline which is connected fixedly in terms of rotation to the gear unit output shaft.

The steering shaft is thus separated in the axial region of the circular spline of the harmonic drive into a first gear

unit input shaft which is connected fixedly in terms of rotation to the steering handle and into a gear unit output shaft which is connected fixedly in terms of rotation to the circular spline.

The gear unit output shaft is connected fixedly to the circular spline and can be arranged rotatably in a frame or housing of the harmonic drive. In this way, it is made possible for the gear unit output shaft to rotate relative to the first gear unit input shaft, as a result of which a positive or negative steering angle can be input into the steering shaft in addition to the steering angle which is input by the driver at the steering handle.

In order to simplify the assembly of the harmonic drive and in order for it to be possible for individual components to be exchanged rapidly, the first gear unit input shaft is connected releasably to the eccentric flexspline. In addition, this has the advantage that the individual components of the harmonic drive can be formed from different materials and known manufacturing methods can continue to be usable for the components. In order to improve the operating comfort of the steering system, there is provision for the torque of the servomotor to be supported on a component, fixed to the vehicle, of the steering system or the vehicle, which is not the steering column itself.

The radially flexible flexspline is preferably fixed in a form-fitting and releasable manner on the first gear unit input shaft, for simple assembly and possible maintenance-induced dismantling with the aid of a connecting element, such as a threaded bolt. A clutch plate which brings about a form-fitting connection which is fixed in terms of rotation is arranged or clamped between the radially flexible flexspline and the first gear unit input shaft. The clutch plate engages

with latching elements in a form-fitting manner into the first gear unit input shaft and the radially flexible flexspline. The eccentric drive core which is connected fixedly in terms of rotation to a shaft of the servomotor is mounted rotatably on the first gear unit input shaft via roller bearings at its axial ends.

The eccentric drive core is arranged radially between the first gear unit input shaft and the radially flexible flexspline and is configured to be as compact as possible radially in order to reduce the installation space requirement of the steering system.

The eccentric drive core preferably engages axially over a large part into the radially flexible flexspline and into the preferably bell-shaped circular spline. This results in an axially and radially compact construction of the harmonic drive and the steering system. The eccentric drive core rolls with a flexible ball bearing in the radially flexible flexspline and deforms the latter in a continuously changing manner. Here, as a function of the cross-sectional shape of the drive core, one or more circumferential sections of the outer circumferential surface of the radially flexible flexspline are in engagement with a substantially cylindrical supporting surface of the circular spline. The circular spline surrounds the flexspline radially. As the circumference of the outer circumferential surface of the radially flexible flexspline is shorter than the circumference of the cylindrical supporting surface of the circular spline, the circular spline, and thus also the gear unit output shaft, rotates by this length difference, said gear unit output shaft being connected fixedly in terms of rotation to the circular spline and in turn being connected to the input shaft of the steering gear. As a result, it is possible for an additional steering angle in the positive or negative direction with

respect to the steering angle which is input on the steering handle to be applied with great precision to the circular spline and the gear unit output shaft.

One or more roller bearings of the eccentric drive core are prestressed axially on the first gear unit input shaft, in order to position said eccentric drive core without play. The axial prestressing preferably takes place with a disk spring which is supported axially on an outer or inner ring of the roller bearing and on the clutch plate. For the preferred floating mounting of the first gear unit input shaft, the latter is mounted via a bearing at one axial end of the gear unit output shaft. The bearing is preferably configured as a needle bush. A bearing journal which can be released in a form-fitting manner preferably engages into the bearing at the axial end of the first gear unit input shaft. The bearing journal has a flats width or an engagement possibility which deviates from the circular shape for a tool, such as a hexagon socket, and thus at the same time forms the fastening element for the form-fittingly releasable fixing of the clutch plate and the radially flexible flexspline on the first gear unit input shaft.

It can be expedient to arrange the servomotor with its housing separately from the housing of the harmonic drive and to connect the servomotor shaft to the eccentric drive core via a gear unit which preferably has a decelerative transmission ratio. The gear unit can be configured as a gear mechanism, such as a spur gear mechanism, a helical gear mechanism or a bevel gear mechanism. Here, the eccentric drive core can preferably be of one-piece configuration with a gear wheel of the gear unit at one axial end. The gear unit can also be configured as a flexible drive mechanism with all suitable and known flexible drive means, such as toothed belts, V-belts, chains, etc., it being possible for the eccentric drive core

to be of one-piece configuration with a pulley wheel or a chain sprocket.

It can also be expedient to configure the servomotor as a hollow shaft motor, a rotor of the servomotor being arranged rotatably about the steering shaft. Here, the hollow shaft of the servomotor can be formed in one piece with the eccentric drive core and can end with the latter in the radially flexible flexspline.

The servomotor is actuated by a control and/or regulating device, the input side of the control and/or regulating device being connected in a signal transmitting manner to a sensor for determining the steering torque, to a sensor for determining the steering angle and/or to a sensor for determining the rotational angle of the steering handle. It can be expedient to configure the sensors as contactless sensors and to configure the steering system as a parameter controlled power steering system or power assistance steering system. The servomotor, the control and/or regulating device, the harmonic drive and the sensors for determining the rotational angle and torque of the steering handle are preferably combined in one housing. The individual components can be arranged separately in the housing in a manner which is shielded from one another.

The overall construction of the superimposed steering system makes it possible for current to be supplied and/or signals to be forwarded between the components of the steering system without additional current guiding devices such as sliders or flat spiral springs or the like. This results in an increase in the operational reliability of the steering system.

The harmonic drive is preferably formed predominantly from steel; at least the radially flexible flexspline and the drive

core are formed from this material. It can also be expedient to form components of the harmonic drive from a nonmetal or a nonferrous metal material. The outer circumferential surface of the radially flexible flexspline can engage into the cylindrical supporting surface of the circular spline with a form-fitting or force-transmitting connection. For the form-fitting engagement, it can be expedient to provide the outer circumferential surface of the radially flexible flexspline with an external toothing system and to provide the cylindrical supporting surface of the circular spline with an internal toothing system. The circular spline having the internal toothing system has a greater number of teeth than the outer circumferential surface of the radially flexible flexspline which is in engagement with the internal toothing system of the circular spline with at least two diametrically opposite circumferential sections of its external toothing system. As a result of the rotation of the eccentric or elliptical drive core in the radially flexible flexspline, all the teeth of the external toothing system of the radially flexible flexspline are brought into contact one after another with the teeth of the internal toothing system of the circular spline during every revolution, as a result of which the circular spline with the gear unit output shaft is rotated by the difference in the number of teeth. Decelerative transmission ratios of approximately from 1:20 to 1:600 can be achieved with a gear stage of the harmonic drive, it being possible for a plurality of gear stages to be connected one after another. Many teeth are in engagement at the same time, with the result that, given the high degree of overlapping, multiple torque loading over comparable gear units is made possible and the harmonic drive has a correspondingly small overall size, and reliable, playfree torque and rotational angle transmission is ensured between the first gear unit input shaft and the gear unit output shaft of the steering shaft as a result of the harmonic drive. If the outer

circumferential surface of the flexspline is in frictional engagement with the supporting surface of the circular spline, any desired transmission ratios can be selected within certain limit ranges.

The variable ratio gear unit is expediently arranged between a steering valve and the steering gear or between the steering handle and the steering valve in the case of a hydraulic power assistance steering system. The variable ratio gear unit is preferably arranged between a steering moment sensor and the steering gear or between the steering handle and the steering gear in the case of an electric power assistance steering system.

It can also be expedient to install the harmonic drive into the steering shaft or the drive train between the steering handle and the steering gear in such a way that the steering handle is connected fixedly in terms of rotation to the circular spline and the radially flexible flexspline is connected fixedly in terms of rotation to the gear unit output shaft of the variable ratio gear unit.

The invention will now be explained in greater detail using an exemplary embodiment and is illustrated using the appended drawing, in which:

Fig. 1 shows a plan view and a partial longitudinal section through a superimposed steering system according to the invention,

Fig. 2 shows a longitudinal section through a harmonic drive of the superimposed steering system in Fig. 1,

Fig. 3 shows a longitudinal section through a further superimposed steering system, and

Fig. 4 shows a detail IV in Fig. 3.

Figure 1 shows a superimposed steering system 1 for a vehicle which is configured as active steering, in a plan view and a partial longitudinal section. The superimposed steering system 1 is formed as an electric superimposed steering system from a servomotor 10 which is supported on a component 17 which is fixed to the vehicle and is not the steering column of the vehicle, from a steering shaft 8 which is connected fixedly in terms of rotation to a steering handle 9, from a variable ratio gear unit 4 which is configured as a harmonic drive 11, and from an input shaft 6 for a steering gear 7. The steering gear 7 can be part of an electric or hydraulic power assistance steering system.

In the exemplary embodiment shown, the steering gear 7 comprises a helically toothed pinion 37 which is arranged at one axial end of the input shaft 6, and a rack 38 which is mounted so as to be axially displaceable and with which the pinion 37 meshes. The rack 38 is fastened in a known and articulated manner to steerable wheels (not shown) of the vehicle with track rod arms.

The servomotor shaft 32 of the servomotor 10 is connected to the harmonic drive 11 via a gear unit 29 which is configured as a flexible drive mechanism 30. The servomotor 10 provides an additional steering angle to the harmonic drive 11, a toothed belt 39 transmitting the torque and the rotational speed of the servomotor 10 to a pulley wheel 31 of the harmonic drive 11 in the exemplary embodiment which is shown in Figs. 1 and 2. The pulley wheel 31 is part of the gear unit 29 and is formed in one piece with a second gear unit input shaft 3 and an eccentric, preferably elliptical drive

core 12. The drive core 12 is formed elliptically at its axial region which adjoins the pulley wheel 31 immediately.

A flexible ball bearing 40 is mounted around the elliptical circumference of said drive core 12. By way of its axial extent from the pulley wheel 31, the drive core 12 engages into a cupshaped, radially flexible flexspline 13 which is formed from resilient steel sheet. The drive core 12 is arranged rotatably on the first gear unit input shaft 2 via roller bearings 20, 20' which are arranged in each case at its axial ends 21, 21' and are formed as groove ball bearings. The radially flexible flexspline 13 has an outer circumferential surface 14 which bears an external toothing system 35 in the axial region of the ball bearing 40. Under the effect of the elliptical widening of the flexspline 13, two circumferential sections 41 of the external toothing system 35 engage in an internal toothing system 36 on a cylindrical supporting surface 15 of a circular spline 16 which is connected fixedly in terms of rotation to the input shaft 6 and a gear unit output shaft 5 of the harmonic drive 11. The circular spline 16 is arranged concentrically with respect to the longitudinal axis 42 of the steering shaft 8 on the input shaft 6 of the steering gear 7 or the gear unit output shaft 5. When the drive core 12 rotates, the elliptical widening takes place in a continuously changing manner along the internal toothing system 36. The circular spline 16 which has an internal toothing system has a greater number of teeth than the radially flexible flexspline 13, as a result of which the circular spline 16 is rotated by the difference in the number of teeth per revolution of the drive core 12.

In order to provide and mount the harmonic drive 11 inexpensively, it is designed in such a functional manner that it can be constructed without a housing, although it is

expedient to arrange it in a housing 43 on the steering gear 7 (cf. Figs. 3, 4).

The steering shaft 8 is separated in the axial region x of the circular spline 16 and is divided into a first gear unit input shaft 2 which is connected fixedly in terms of rotation to the steering handle 9 and at the other end of which the drive core 12 and the radially flexible flexspline 13 are arranged, and into a gear unit output shaft 5 which is connected fixedly in terms of rotation to the circular spline 16 and the input shaft 6. In this way, the gear unit output shaft 5 can be rotated by the harmonic drive 11 relative to the first gear unit input shaft 2 and a steering angle which is dependent on driving and vehicle parameters can be input into the steering shaft 8 ahead of the steering gear 7.

For relatively easy assembly, for any possible simple exchanging of parts of the harmonic drive 11 and in order for it to be possible also to manufacture the parts of the harmonic drive from different materials using known manufacturing processes, the first gear unit input shaft 2 is connected in a form-fittingly releasable manner to the radially flexible flexspline 13. The torque transmission from the first gear unit input shaft 2 to the radially flexible flexspline 13 is carried out by a clutch plate 19 which protrudes into the radially flexible flexspline 13 and the first gear unit input shaft 2 with the aid of latching elements. The clutch plate 19 is fixed releasably on the end side of the first gear unit input shaft 2 which protrudes into the circular spline 16, by way of a connecting element 18 which is configured as a threaded bolt and protrudes into the first gear unit input shaft 2.

As Figs. 1 to 4 show, a disk spring 24 is clamped axially between an inner ring 23 of the roller bearing 20 and an

annular flange 44 of the radially flexible flexspline 13. The disk spring 24 prestresses the roller bearing 20 and positions the drive core 12 on the first gear unit input shaft 2 without play. The disk spring 24 can also act on the outer ring 22 of the roller bearing 20.

In a longitudinal section through a superimposed steering system 1, the servomotor 10 of which is configured as a hollow shaft motor 33, Figures 3 and 4 show that the first gear unit input shaft 2 does not necessarily have to be mounted in a floating manner in the harmonic drive 11 which is configured according to the invention, but rather that the first gear unit input shaft 2 can be mounted by way of a bearing 25 in the circular spline 16 or in the first gear unit output shaft 5. The bearing 25 is configured as a needle bush 26 and radial bearing, a form-fittingly releasable bearing journal 27 on the end face of the first gear unit input shaft 2 protruding into the needle bush 26. The bearing journal 27 has a hexagon socket and thus serves at the same time as a connecting element 18 for fixing the clutch plate 19 and the radially flexible flexspline 13 to the first gear unit input shaft 2. In all the exemplary embodiments shown, a head of the connecting element 18 protrudes axially into the gear unit output shaft 5, as a result of which the overall size of the harmonic drive 11 becomes more compact.

The hollow shaft motor 33 is arranged coaxially with respect to the longitudinal axis 42 of the steering shaft 8. The first gear unit input shaft 2 of the steering shaft 8 penetrates the servomotor 10, a rotor 34 of the servomotor 10 being arranged on the servomotor shaft 32 so as to rotate around the steering shaft 8. The servomotor shaft 32 is of one-piece configuration with the drive core 12 and is mounted with the aid of the roller bearings 20, 20' and the needle bush 26 in the gear unit output shaft 5 and a further needle

bush 45 between the first gear unit input shaft 2 and the servomotor shaft 32. The further needle bush 45 is arranged at an axial spacing from the roller bearings 20, 20'.

The stator 46 of the servomotor 10 is arranged fixedly on the housing 43 which encloses the harmonic drive 11, the servomotor 10 and a control and/or regulating device 47. The harmonic drive 11, the servomotor 10 and the control and/or regulating device 47 are arranged in the housing 43 such that they are separated spatially and are shielded from one another.

Instead of the form-fitting engagement of the outer circumferential surface 14 of the flexspline 13 with the internal toothing system 36 of the circular spline 16, it can be expedient to provide a frictional engagement of the outer circumferential surface 14 with the cylindrical supporting surface 15 of the circular spline 16, as a result of which any desired decelerative transmission ratios can be selected, the denominator of which is not an integer. Moreover, fine tooth spacings, corrugations or knurling can be provided.

LIST OF DESIGNATIONS

1	Superimposed steering system
2	Gear unit input shaft, first
3	Gear unit input shaft, second
4	Variable ratio gear unit
5	Gear unit output shaft
6	Input shaft
7	Steering gear
8	Steering shaft
9	Steering handle
10	Servomotor
11	Harmonic drive
12	Drive core, eccentric
13	Flexspline, radially flexible
14	Outer circumferential surface, of 12
15	Supporting surface, cylindrical
16	Circular spline
17	Component, fixed to the vehicle
18	Connecting element
19	Clutch plate
20, 20'	Roller bearing
21, 21'	End, axial of 12
22	Outer ring
23	Inner ring
24	Disk spring
25	Bearing
26	Needle bush
27	Bearing journal
28	Depression
29	Gear unit
30	Flexible drive mechanism
31	Pulley wheel
32	Servomotor shaft
33	Hollow shaft motor
34	Rotor

35	External toothing system
36	Internal toothing system
37	Pinion, helically toothed
38	Rack
39	Toothed belt
40	Ball bearing
41	Circumferential section
42	Longitudinal axis, of 8
43	Housing, of 11
44	Annular flange
45	Needle bush
46	Stator
47	Control and/or regulating device
48	
49	
50	
x	Region, axial of 16